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(54) VIRTUAL REALITY SYSTEM

(57) A visual virtual reality system including a display mounted in relation to the viewer's head, means for measuring the orientation and position of the viewer's head or eyes, means for generating a first image dependent upon this head data, means for transforming said first image depending on the differences between the head data used to calculate said first image and the most recently estimated head data respectively, and means for displaying said transformed image on said display.

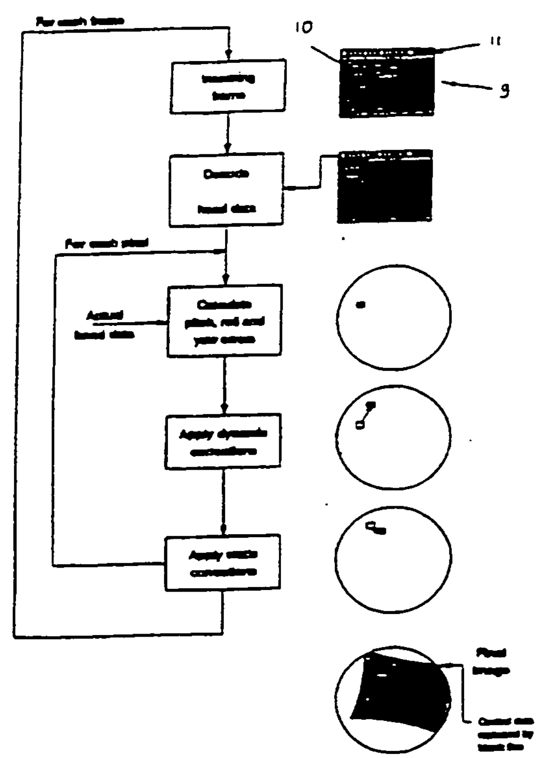

Fig. 3

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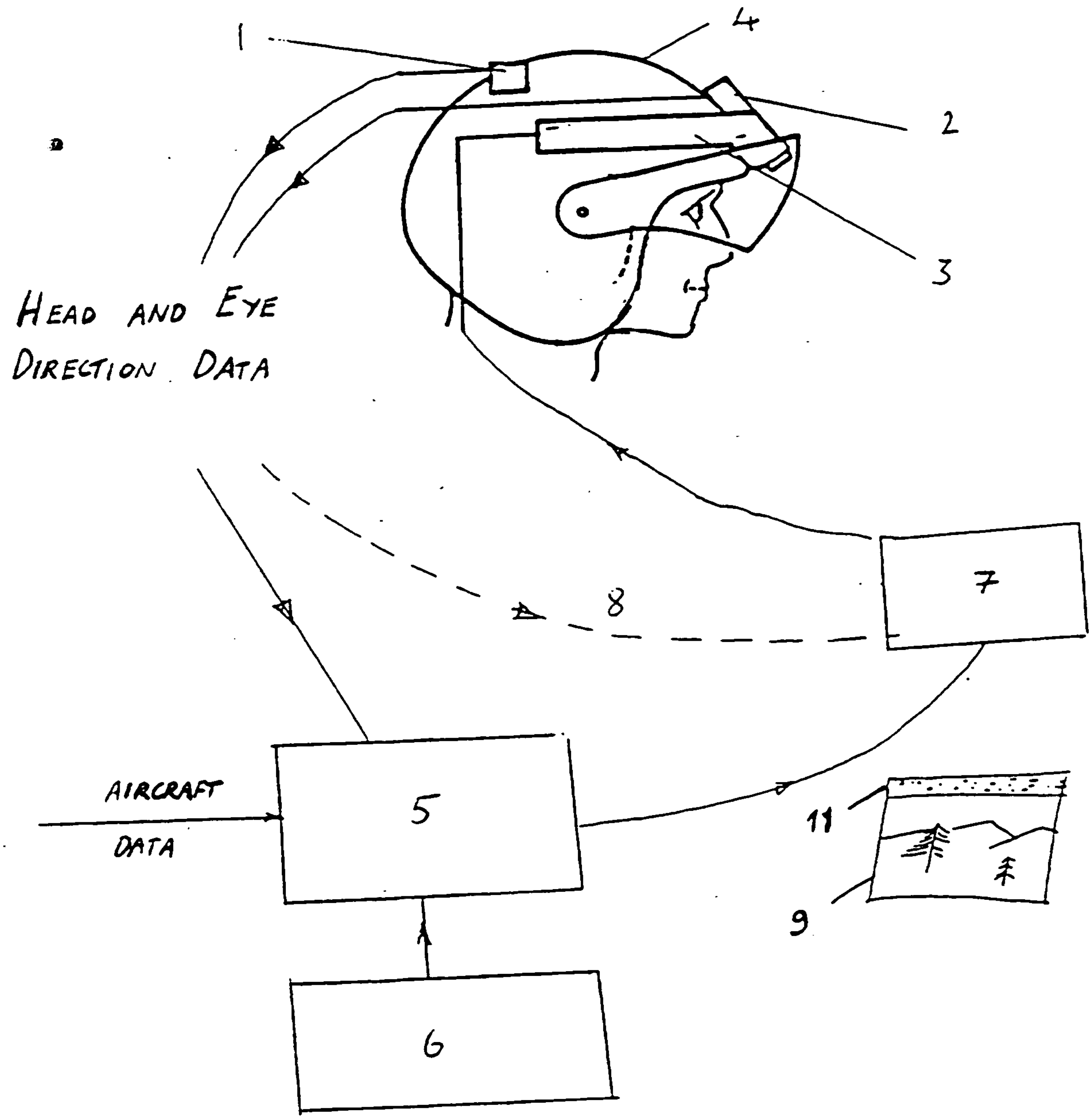
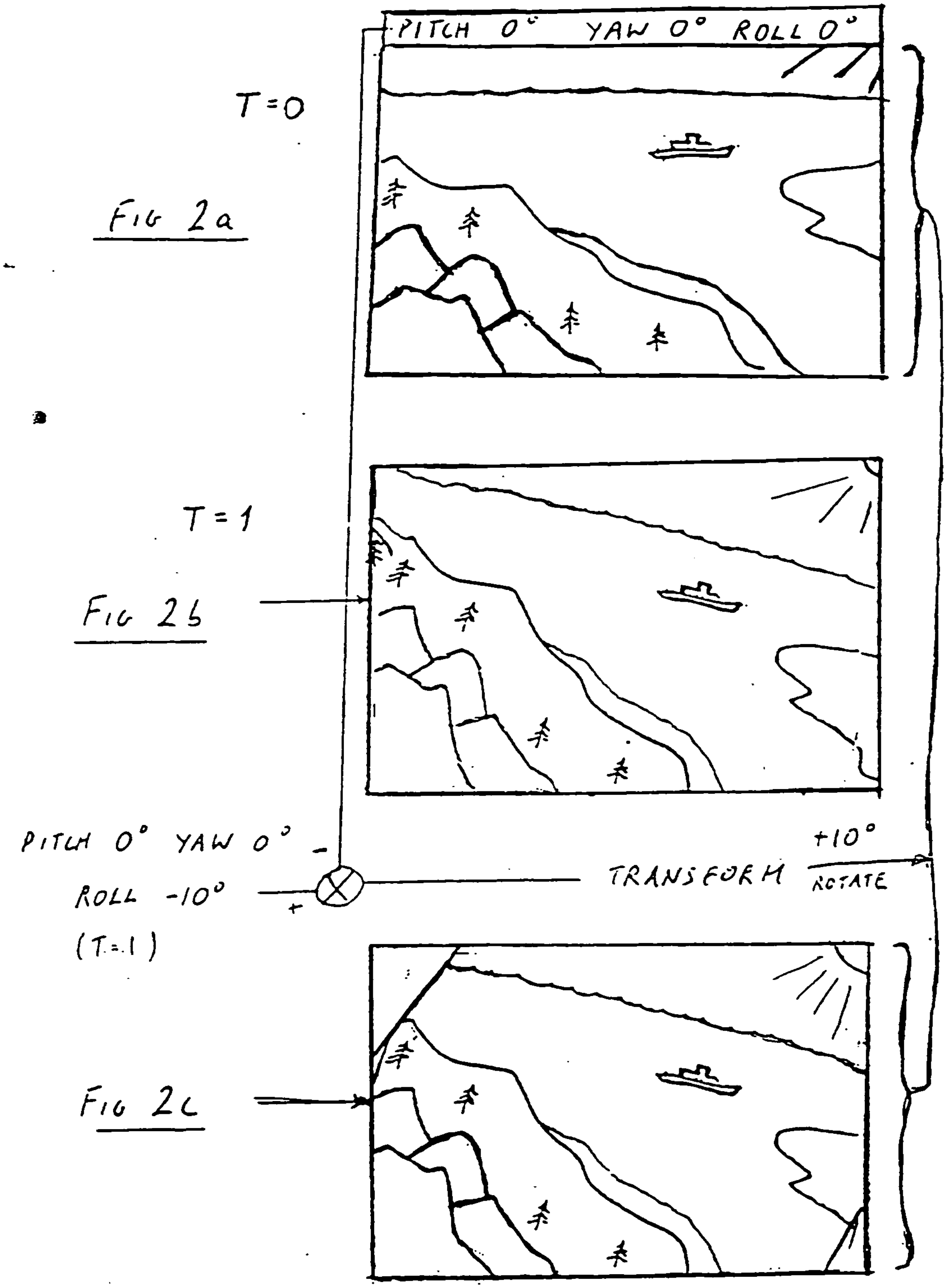
FIG 1




PITCH 0° YAW 0° ROLL 0°
T=0
FIG 2a
T=1
FIG 2b
PITCH 0° YAW 0°
ROLL -10°
(T=1)
-
+
TRANSFORM
+10°
ROTATE
FIG 2c

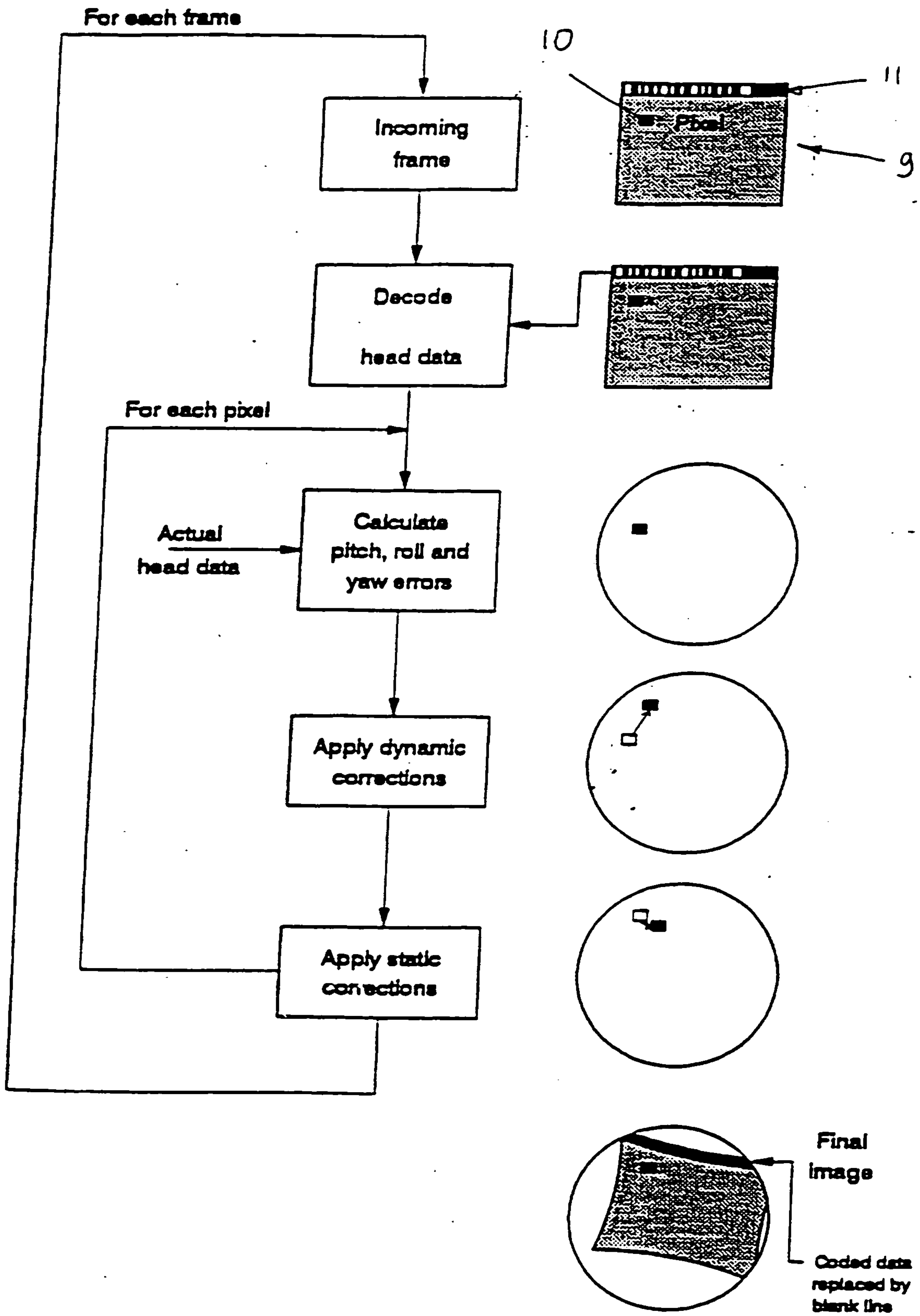

For each frame
10
11
Incoming frame
Pixel
9
Decode head data
For each pixel
Actual head data
Calculate pitch, roll and yaw errors
Apply dynamic corrections
Apply static corrections
Final image
Coded data replaced by blank line

FIG. 3

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VISUAL VIRTUAL REALITY SYSTEM

The invention relates to visual "virtual reality" systems in which computer generated images simulating the outside world are displayed to a viewer. The invention has particular but not exclusive application to "virtual cockpits" wherein an aircraft pilot's perception of the outside world through which he is flying is augmented artificially using a helmet mounted display.

Virtual reality systems generally comprise a head mounted display device such as a cathode ray tube (CRT), in which images are presented to the viewer. The display device is connected to an image generator which is further coupled with an image information database which the image generator uses in order to generate an image. The image generator usually has inputs from external sensors mounted on the viewer's head which provide positional and orientational data to the image generator. Depending on the position of orientation of the viewer's head and, in the case of virtual cockpits, the orientation of the aircraft, an image is generated by the image generator and sent to the display device, this image representing the real world as viewed without the display, as accurately as possible.

In virtual cockpit systems the image database may contain terrain data covering a geographical area e.g. three dimensional data showing height of the land depending on its grid co-ordinates. Further the image presented to the pilot may be coloured or patterned depending on the type of terrain; e.g. rivers, forests, fields, snow, etc. may be shaded differently. As the position and orientation (attitude) of the pilot or aircraft changes, the image will need to be updated and it is the task of the image generator to extract the necessary information from the sensors and data base, generate the image and present it to the display means. As mentioned, data concerning the position and the orientation of the pilot's head is provided to the image generator and can be measured by sensors located on the head so that e.g. position and pitch, yaw and roll of the head are measured and fed to the image generator. The image generator will then present new images to the pilot via the display depending on head orientation and aircraft data. Eye orientation sensors may also be used to enable the orientation of the eye to be similarly ascertained and used in the image generation process.

A problem with these systems is that a number of time delays arise between the time when the raw head data are measured and the time when the image is displayed; as a result the image displayed to

the viewer may be out-of-date and not represent what the viewer should see; he may for example, have moved his head in the meantime. The term "cycle time" refers to the time it takes to obtain head data and to use such data to determine and generate the appropriate image, and to display the image on a screen to the viewer. The image generator is the main source of the delay between head movement and image display and this delay is dependent on the power of the image generators, the complexity of the imagery being drawn and the video standard of the display device.

The cycle time also includes the time it takes for each frame of the image to be taken from the image generators and displayed on the head mounted display. In some examples the image generators produce analogue video signals from a frame buffer which is not simultaneously being filled by the image construction process. The image display starts almost immediately but it takes a complete frame time to read and display all the image and so for a PAL system, it takes 40 ms to display the image.

The image display therefore starts at some time after the head data is taken, and this leads to problems in perception. If the head moves after the head data has been collected then the image is constructed from the wrong viewpoint. The head is quite capable of rotating at rates well in excess of 360°/s. A 60Hz graphics system would have an intrinsic delay of 16.7 ms leading to an additional image shift of 1.67 ° at a head rotation of 100°/s due to the graphics construction alone, whilst for a 25Hz system the initial image shift is 4°. Calculation of these figures excludes the delays due to the head sensors and data transmission, and assumes that it takes only one frame to construct the picture. Since each image also takes one frame period to output, the image shift will change during this draw time. For a scanned device such as a cathode ray tube (CRT) with a short persistence, the image will appear to shear in visual space along the direction of head motion, with the pixels which are drawn last having the greatest errors. A long persistence phosphor will tend to produce images which are smeared as well as sheared. This effect is taken to its limit in devices such as back-
illuminated active matrix LCD's where the image is held for the whole frame. The image is not seen as distorted, but when the viewer is fixating on a feature in the external scene, head movement during the display time will smear the entire field. A significant consequence is that the head carries the imagery with it and the image only moves back to its correct position in the world when head motion ceases. For voluntary head movements such as a tracking task, the pilot will have to pause to let the picture settle before he can use auxiliary systems such as e.g. head or eye target designation systems with confidence that he is aiming in the right direction. The false motion cues

generated by the inappropriate movements of the imagery may also cause disorientation and nausea. Involuntary head movement also cause many perceptual problems. A large proportion of cockpit vibration in fast jets lies within the 0.5 to 20Hz region and this vibration is predominantly vertical which will cause continual pitching head movements which, with image display delay, results in a continuously vibrating image.

One way of reducing the delay between head movement and image display which may alleviate such problems is by prediction of head movement. Coarse prediction of head data can be generated by calculating the head velocities and accelerations. Although such a prediction works reasonably well for smooth head movements with minimal noise in the head data and for short delay, it cannot accommodate rapid changes in acceleration; in addition the delay time has to be known and constant.

It is an object of the invention to provide a system which will greatly minimise the above mentioned problems associated with the time delay arising between measuring head data and displaying a generated image.

The invention consists of a visual virtual reality system including a display mounted in relation to the viewer's head, means for measuring the orientation and position of the viewer's head or eyes, means for generating a first image dependent upon head data, means for transforming said first image depending on the differences between the head data used to calculate said first image and the most recently estimated head data respectively, and means for displaying said transformed image on said display.

The invention allows therefore the most recently measured head data (which is obtained very quickly in comparison to the time it takes to generate an image) to be used to transform the image which is generated using older head or eye orientation data during image display so that it is more up to date. Transformation of the image is performed very rapidly compared with the time it takes to generate, the image. The transformation generally shifts or rotates individual pixels of the image generated to make it resemble what the viewer should see according to his head movement. At frequent intervals during the image display a corrector uses the head orientation data transmitted with the image by the image generator and the most recently measured head orientation data and according to the differences therebetween, transforms image.

Optionally the "most recent measured " head data used to compare with that data transmitted with the image, may be "predicted" head data as opposed to the "actual measured" head data.

By way of example only one embodiment of the invention will be hereinafter described with reference to the drawings of which:

Figure 1 shows a schematic view of a virtual cockpit configuration with a block diagram representing a virtual reality system according to the invention.

Figure 2 shows an example of how the generated image may be transformed according to the invention.

Figure 3 shows a more detailed representation of the working of the system using a flow diagram.

Figure 1 shows a schematic view of a virtual cockpit system according to the invention which includes head orientation sensors 1 an eye direction sensor 2 and a binocular display unit comprising a cathode ray tube (CRT) 3, all mounted on a pilot's helmet 4. The head orientation sensors comprise movement potentiometers whose output signals are therefore dependent on the movement of the pilot's head; allowing the parameters of pitch, roll and yaw and position of the head to be measured. These parameters are assumed to change constantly according to movement of the pilot's head. The data from the head and eye orientation sensors are input into an image generator 5 which is connected also to a database 6. The database contains terrain information which includes grid co-ordinates, terrain height, terrain type. Also input into the image generator is aircraft, position data which includes aircraft location and attitude. The function of the image generator is to generate, according to all data, the correct image which the pilot should see in reality if looking out of the cockpit. The image data are then transmitted to the display unit which emits an image to the pilot, via a corrector 7. The image data transmitted to the display corrector is accompanied by data on the head which was used to generate that image. Advantageously these data are stored as part of the image frame itself. The system also includes an additional path 8 wherein current head orientation data is supplied directly to the corrector, this data requires little or no processing and therefore the transmission time is very short. The function of the corrector is to take the incoming image and transform the image displayed by the display unit depending on the

difference in the head data transmitted with the image and the current data transmitted directly to the corrector along path 8.

Figure 2 shows the operation of a visual virtual reality system showing how movement of the wearer's head would change the image to be displayed so as to represent the change in image that the viewer would see in reality.

Figure 2a shows a coastal view generated by the image generator at a point in time (T=O) using a particular set of head data, when the pilot's head is in a forward unrotated position.

Figure 2b shows the view which would be seen by the pilot out of his cockpit at a later time (T=1) in reality if he rotated his head anti clockwise by a small angle. The same effect would be obtained if the aircraft rolled a small amount anti clockwise. In prior art systems the parameters of head orientation are used by the image generator to generate a fresh image and display it to the pilot, but it takes a relatively long time to generate the new image. By the time it is to be presented to the pilot, the pilot may have moved his head again and this image is out of date.

Figure 2c shows the image that is displayed by the system according to the invention. As can be seen, the image displayed in figure 2c closely resembles the actual view shown in 2a. Transmitted with the last image generated from the image generator (i.e. that of figure 2a), is the head orientation data associated with (used to generate) that image, as shown in the top box of figure 2a. The up-to-date (current) head data are rapidly available to the display corrector. The difference between the data sets is computed to indicate the movement of the pilot's head that has taken place since T=O. In the example given the differential is a rotation of the head in the roll axis anti-clockwise by 10°. This differential is used by the display corrector to transform the image, which in the example is a rotation of the image clockwise by the appropriate amount i.e. 10°. The display then shows the transformed image.

Figure 3 shows a more detailed representation of this process as a flow diagram. The incoming frame (image) 9 is generated from the image generator. This frame or image comprises pixels 10. Part of the frame, the top line 11, is dedicated to storing head orientation data that was used to generate that image. The corrector then decodes the head date from the incoming image (frame) and the pitch, roll and yaw errors are then calculated from actual head data and the dynamic corrections are applied to the cathode ray tube image. This is done for each pixel. The effect on a

pixel to be displayed on the CRT is shown on the right hand side of the figure, the CRT face plate represented by a circle. The pixel will be shifted in the CRT face plate according to the differences in actual and incoming frame head orientation data, e.g. if there is a discrepancy in roll, pitch or yaw data, only then the corrector would shift all the pixels appropriately. The corrector additionally in this embodiment applies static corrections to overcome optical distortions so as to match the image with the optics which transform the real images on the CRT. The above cyclic process is performed for each frame generated by the image generator. Finally when transmitting the CRT image the coded data will be replaced by a blank line.

Although so far this specification teaches that displayed images are transformed according to changes in head orientation that have taken place subsequent to the generation of the image, it should be understood that the inventive principle also envelops the principle whereby virtual reality systems which employ eye direction sensors to generate data for image generation, can also be provided with means to transform the image generated dependent on differences between eye direction data used to generate the image and current eye direction data. Thus the term "head data" should be interpreted as including reference to head orientational and positional data and/or eye direction data.

Claims

1. A visual virtual reality system including a display mounted in relation to the viewer's head, means for measuring the orientation and position of the viewer's head or eyes, means for generating a first image dependent upon this head data, means for transforming said first image depending on the differences between the head data used to calculate said first image and the most recently estimated head data respectively, and means for displaying said transformed image on said display.

2. A visual virtual reality system as claimed in claim I wherein head data used to calculate said first image is transmitted to the transformation means, as part of the image itself.

3. A visual virtual reality system as claimed in claim 2 wherein said head data are stored digitally in a row(s) or column(s) of the transmitted image.

4. A visual virtual reality system as claimed in claim 3 wherein said row(s) or (columns) are replaced by blank lines in the final displayed image.

5. A visual virtual reality system as claimed in claims 1 to 4 wherein the most recent estimated head data used by said transformation means are those directly measured.

6. A visual virtual reality system as claimed in claims 1 or 2 wherein the most recent estimated head data used by said transformation means are predicted.

The Patent Office

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Patents Act 1977
Search Report under Section 17

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Int Cl (Ed.6): G06T 3/00, 3/20, 3/40, 3/60, 15/00 - 15/70

Other: ONLINE: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2 201 069 A	[Waldern] See p7. ref to needed recalculation of view.	1
X	EP 0 637 815 A2	[CANON] See whole doc.	1

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Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.